Indian J. Phys. **65B** (1), 44-54 (1991)

Diathermy and cryo-application in ophthalmology

A K Banerjee and Anita Banerjee
Regional Institute of Ophthalmology, Calcutta Medical College and Hospitals, Calcutta-700 073, India

Abstract : Application of diathermy and cryo has important role in Opthalmology. The diathermy is heat coagulator which by means of aseptic inflammation produces adhesion between two or more tissues. Cryo also produces same effect but where instead of heat, cold is applied as therapeutic agent. Both are effective in retinal detachment, retinoblastoma, angioma, glaucoma etc. but cryo can be used more extensively in eye. It also acts on keratitis of bacterial and viral origin, chemical burns of cornea, recurrent pterygium etc.

The disadvantages of diathermy are more than cryo therapy. In diathermy reaction is more severe and prolonged and causes more tissue necrosis. In diathermy vitreous is heated up with subsequent production of vitreous bands and secondary detachment of retina is more. Not only that results with diathermy are also unpredictable and cumulative action of diathermy is more common. But cryotherapy has none of these advantages. It causes less damage to the sclera. It can be used over blood vessels. Vitreous bands are minimal and cumulative effect is less in cryopexy.

In cryotherapy due to freezing and subsequent thawing the cell membrane is ruptured leading to denaturation of cell protein and thermal shock occurs due to rapid change of temperature above freezing point. Cryotherapy also causes vascular stasis in tissue. The freezing temperature of cryo applied in eye is between 20°C to 80 C. The material used in cryo for freezing are liquid air, liquid oxygen, liquid nitrogen, carbon dioxide and freon gas. Cryo has definitely advantageous role in Ophthalmology than diathermy.

Keywords : Diathermy, cryogenics, applications.

PACS Nos : 87.55. Dx, 87.55. Hb

1. Introduction

The organisation of a multidisciplinary seminar or workshop involving physicists, clinicians and experimental medical scientists with wide divergence in the background of their teaching and training and with different view-points is a rare event in our country, no doubt, but the importance and practical utility of such an endeavour can not be underrated because such an occasion helps not only in establishing the desirable areas of contact and co-operation of the involved disciplines but helps more in identifying the areas of confusion, mainly arising out of the mutual exclusiveness of thinking persued by the different disciplines, and

breaking the errected barriers and thereby it undoubtedly paves the path of greater co-operative and co-ordinated efforts to help in further progress of science in general and in metigating the suffering of the ailing humanity at large. Besides, this provides an opportunity to explore the vistas hitherto untrodden and gives a clarion call to conquer the obstacles by utilizing the growing knowledge, fast accummulating in the spheres of physical, biological and medical science, by honing them effectively to develop suitable technology to harness fully the expertise in the desired direction of rendering service to the humanity in progress and peace, in the relief of human misersies and in establishing a greater and lasting overall harmony.

The subject under discussion provides such an area hinted above and the topics cover a vast areas of accumulated knowledge obtained from different disciplines of science, so they can be approached from different view-points. Here an attempt will be made very briefly to high-light some of the changing arenas of our mutual interests and common concerns from the angularity of an Ophthalmologist in bare out-line.

2. Diathermy in ophthalmology

Diathermy in Retinal Detachmment Surgery was introduced in 1930 and has the following classifications.

2.1. Diathermy or radio-frequency currents :

Alternating electric currents of high frequency usually expressed in Megattertz (MH_Z). Written mathematically as

$$f(\text{in caps}) \times \lambda \text{ (in meters)} = 3 \times 10^8 \text{ meters/second (velocity of light).}$$

2.2. Types of diathermy commonly used in ophthalmology :

(i) Surface diathermy of ocular coats (0.5 to 13 MH_Z) done :

(a) to produce aseptic chorioretinal adhesion e.g. retinal detachment surgery.
(b) destruction of small intraocular tumors usually benign.

(ii) Cutting diathermy used as a knife to deal with highly vascular lesions of ocular adnexa.

(iii) Under-water diathermy in some Vitrectomy procedures.

2.3. Effects of surface diathermy to the tissues in general :

(a) Only the effect of heat produced is utilized clinically.
(b) Causes of heat production :

(i) Oscillation of ions, consequent to reversal of diathermy current with loss of electric energy due to electric resistance met in tissues.

(ii) Loss of energy due to rotation back and forth of *'Dipoles'* (i.e. molecules with electric charge) caused by tissue viscosity.

2.4. Quantitative aspect of temperature rise :

It depends on : (i) The cooling mechanism of the surrounding tissue by way of conduction and convection. (ii) Frequency of Radiocurrent used : capacity of tissue to absorb electric power is determined by its resistivity (R) or conductivity ($1/R$) which is a function of frequency of current used.

3. Types of diathermy used

(a) *Low-frequency*—current flows exclusively through the extracellular medium with high resistance and with lateral spread.

(b) *High-frequency*—the cell-membrane becomes less insulating with gradually increasing intracellular flow of current, but having increased resistance and less lateral spread. Tissue burn will be smaller but stronger with same current density, with high-frequency current ; danger of production of "*Heat Spots*" especially in multi-layered structure like eye-coats are real.

3.1. Damped vs undamped current :

(a) *Damped current*—requires high peak voltage, delivery of unequal current density, tendency to spark (with explosion in tissue with tendency for more haemorrhage) with tissue heating slow and more spreading of current, so making it difficult to control the power delivery accurately.

(b) *Undamped diathermy*—preferable as delivery of constant intensity current with no dangerous built of periodic high voltage can be effected.

3.2. Surface diathermy of ocular coats :

This involves use of two electrodes.

Small active one on Sclera and the indifferent one from the patient backing the current to the machine. Current travel in a direction perpendicular to the interface between the electrode and the tissue with some inevitable lateral spread. Sclera is most susceptible to the resultant heat injury as high current density occurs there. But the scleral damage can be reduced by (a) decreasing the energy delivery compensated by increased exposure-time. (b) Undermining the sclera by lamellar dissection. (c) By increasing current frequency to 300 MH_2 or more.

3.3. Degree and extent of chorio-retinal burns produced :

It is influenced by the shape and size of the electrode used.

(a) Pointed electrode : more efficiently burns deeper tissue but inflicts more damage to the sclera.

(b) Flat electrode : heats mainly the perimeter of contact point.

More consistently desired effect is possible with optimised diathermy machines to come in the field in near future.

3.4. Requirements of an optimised diathermy :

Capacity to generate fairly high frequency current with provision of voltage control along with frequency control. Crystal controlled frequency generator and voltage regulated power amplifier will be a better one. Shielded or coaxial cable with provision having length of cable variably fixed. At each power setting : output impedance of machine be equalised to average tissue resistance (approx. 200 ohms) should minimize damage to the Sclera.

3.5. Technique of diathermy application employed :

This varies with aims.

Common uses of surface-diathermy in ophthalmology are

(a) retinal detachment surgery to produce aseptic chorioretinal adhesion and to seal retinal breaks.

(b) removal of IOFB by posterior route, usually through Pars Plana route.

(c) destruction of some intraocular tumours usually benign ones and

(d) cyclo-diathermy in absolute glaucoma, to relief intractable pain.

3.6. For retinal detachment surgery diathermy is used with the following aims e.g. :

(a) as localising and marking.

(b) production of tissue destruction and damage, to desired size and degree, to produce chorio-retinal adhesion.

(c) release of sub-retinal fluid if considerable to oppose retina to underlying choroid.

3.7. For optimal result following points should be kept in mind during retinal detachment surgery :

(a) To produce even a mild retinal vesible mark—

More power is needed in Wet Sclera which dissipates current more.

Less power is required if the electrode is pressed firmly.

More power is needed to effect same result as one moves along sclera further from the limbus.

(b) When voltage is so adjusted as to require 3-5 seconds to cause mild retinal reaction : this minimises scleral injury.

(c) Transistorised model yields more consistent and predictable effect than the usual vacuum tube-machine available now in the market.

4. Cryo-application in ophthalmology

Brief history of cryo-application in medicine.

Cold was found applied : (a) in compound skull fracture and infected chest wound (2,500 B.C.). (b) to control haemorrhage, swelling and gout (Hippo-

crates). (c) as local anaesthetic agent (1050 A.D. by a Anglo-Saxon unknown Monk). (d) local refrigeration especially in limb surgery was used in the middle of 19th century. (e) hypothermia as a concept in anaesthesia and surgical aid, especially in Cardiac and Neurosurgery was advocated and gradually developed in the middle of 20th century.

4.1. Methods of cold-production :

Mixture of acetone and dry ice, $-15°C$; Freon $-40°C$; Liquid N_2 $-180°C$ were tried. (a) gradual extension of Cryo in Urology, Ophthalmology, otolaryngology, gynaecology etc. is seen for last two decades or so.

4.2. History of use of cryo in ophthalmology :

(a) Cryo-extraction of lens.

(b) Chorio-retinal adhesion-formation was practised long before as far as in 1934 with diathermy.

(c) Cryo-immunology is a new exploration in Medicine with potentiality of high promises.

5. Cryo-biology

Some fundamentals in surgical context effect, of lower temperature and rate of freezing :

The lowest temperature to which a tissue is subjected and the rate at which the heat is removed greatly influence the integrity of cell-system :

(a) Higher range of temperature i.e. $0°C$, to $-130°C$ (the recrystalization point of water).

(b) Intermediate range of temperature $-130°C$ to $-170°C$.

(c) Low temperature i.e. below $-170°C$. Rate of Freezing : Slow, Rapid or High-rapid freezing.

5.1. Clinical classification of stages of freezing :

This may be,

Cryo-adhesion ; Cryo-solidification ; Cryo-inflammation ; and Cryo-degeneration.

Use of a suitable time-temperature regime under controlled conditions permits one to get the last two ones.

5.2. Physico-chemical basis of cryo-biology :

It involves twin process of cell-injury inflicated during freezing and thawing phase.

Freezing : Change in the water concentration in extra- and intracellular milleu as well as effects of low temperature itself modifies the normal cellular activities leading to loss of cellular function and gradually cellular integrity as well.

Water being the major component in cell functions and solvent, as structural component of proteins and other molecular assemblages, so the diverse injurious effects in different levels can be compounded.

Phase-transformation : With removal of latent heat of crystallization, there occur Dehydration and Solute-concentration with added change in pH all aiding and abating to cumulative damaging effect.

However, points to be noted here are :—

(a) Freezing in tissue is not an isothermal process ; being completed over rather a wide temperature range, till last "Eutectic temperature" of the system is reached.

(b) The peculiar nature of the cooling curve for different agents to be kept in mind.

(c) In the 4th and 5th segment of cooling curve : Solid state cooling takes place when rapid cell-destruction occurs.

5.3. Effects of different rates of cooling on tissues :

Slow freezing :

(i) Essentially ice crystals are formed in extra-cellular spaces of tissue and compress the cells with disturbed sterio intra-cellular relationship.

(ii) The rate depends on factors like—(a) Cooling rate ; (b) Permeability of cell membrane affected by—Vapour Pressure differential between ice and super-cooled water and Osmotic gradient etc.

Rapid freezing results (i.e. cooling rate tens to one hundred degree C/Min) :

(a) Simultaneous freezing occurs with formation of ice both in intra-cellular and extra-cellular spaces.

(b) Water inside the cell undergoes supercooling, nuclear formation and rapid spread of ice leading to rapid disorganisation of cell structures and cellular death eventually.

High rapid freezing (i.e. cooling rate exceeding one hundred degree C/min) :

Results in exclusively intra-cellular ice formation with extensive cell destruction occuring very rapidly.

5.4. During thawing phase : tissue effect :

(i) A cell with part of its membrane is subjected to opposite osmotic activity leading to rapid entry of water in one area and loss of water in another area.

(ii) Freeze-thaw procedure is thus a potentially destructive modality to tissues depending however on time-temperature regime used and specific composition of tissues concerned.

(iii) But poor conductivity of biological materials surrounding the zone where Cryo is directly applied adds greatly the useful safty-factor to the Cryo-Surgeon's destructive procedure.

(iv) Heterogeneous cell-population in most of the treated tissues is another unpredictable element, a double edged conditioning factor which must be carefully noted.

6. Cell-survival in cryo-surgical freezing in vivo

(i) Cryoprobe acts as a heat-sink.

(ii) Creation of following resultant differential gradients in the affected zone. viz., Gradients in temperature ; Gradient in the distribution of ice and water extending outwards from the effective EUTECTIC boundary ; Gradient in solute concentration in liquid phase ; Distribution of ice intra- and extracellularly ; Effect on different enzyme, suspension or disfunction in the living organisation as a whole.

The result and effects are a summation of all these known and unpredictable factors : General rule is thus to maximise lithality, attempts should be made to cool cells below $-20^{\circ}C$ with more slowing of the rate of thawing achieved by any means.

7. Physical principles of cryo-technique

It is known that some changes of physical state absorbs heat.

Refregerators work by absorption of heat with recycling of the coolant gas back to the container.

Cryoprobe works on the principle of refregeration with some modification i.e. cooling for cryo therapy does not require the coolant be in the liquid state because *Cold can be produced by allowing the* coolant gas to decompress from high pressure to atmospheric pressure without change of state (Joule-Thomson effect) in the Cryo-tip made of Silver the coolant gas used then returns to the console where it is release in air of operation theatre.

Boiling point at atmospheric pressure of some common gases.

1. $CO_2 - 79.5^{\circ}C$; $NO_2 - 90^{\circ}C$; $N_2 - 196^{\circ}C$.
2. Freon -50° ; with $CO_2 - 60^{\circ}$; with $NO_2 - 20 - 80^{\circ}$; with $N_2 - 100^{\circ}$ or above.

(i) Rate of cooling depends on the boiling point of coolant used.

(ii) Regulating the rate of decompression including suitable design of orifice diameter of the cryo-machine.

(iii) The rate of extraction of heat from the surrounding tissues is a biological variable.

(iv) Rate of Thawing is remarkably slower and the temperature of −2.2°C (the freezing point of tissue fluid) is maintained at the surface of ice hemisphere till thawing is completed.

This rate can be influenced by incorporated heating device in the cryo-probe or by simply dropping normal saline on the tip.

Refreezing augments lethal effect of cells disproportionately.

8. Causes of popularity of cryo in ophthalmology and areas of application

8.1. Causes for popularity :

(i) Eye is easily accessible.

(ii) Heterogenous tissue comprising the eyeball adds the needed safty-factor, so controllable is the reaction elicited.

(iii) Recent advance in low temperature technology providing of freezing temperature to small area of contact.

8.2. Use of cryo-application in ophthalmology :

Broad areas of application are

(i) Cryo-extraction of lens.

(ii) To induce chorio-retinal adhesions and scar formation in (a) Retinal Detachment, (Curatively Prophylactically) ; (b) Pars Plana Vitrectomy ; (c) Removal of I.O.F.B. by posterior route.

(iii) To induce focal destruction of selected tissue or small suitable intra-ocular tumor including retinoblastoma. Von Hippel's diseases, Coat's disease or peripheral neovascularisation of fundus oculi.

(iv) Cyclo-cryotherapy is practiced in some forms of glaucomas e.g. aphakic glaucoma with vit. in A.C. or absolute glaucoma.

(v) Miscellaneous group comprises use in the treatment of corneal ulcer, Pterygium etc.

8.3. Some considerations of two most common uses of cryo in ophthalmology :

8.3.1. Cryo extraction of lens :

Salient points are

(a) At about −30°C, ice mass formed encompasses besides lens capsule, a portion of cortex and even nucleus of the lens.

(b) Less tendency to capsule rupture because unlike intra-capsular forcep-delivery here the traction-force is distributed evenly over a wider area.

(c) Even a small tear of lens capsule may be tackled during operation because ice ball seals it.

(d) Indication, contra-indication complications following cryo-extraction are numourous and does not require consideration here.

8.3.2. *Cryo-application for retinal detachment surgery :*
Salient points are

(a) Detection and localisation of actual retinal hole or hole-producing predisposing pathologic lesions in the fundus.

(b) Sealing of the retinal holes by a firm Chorio-retinal adhesion.

(c) Formation of a suitable barrage and buckling of retinal coats posterior to the actual or potentially dangerous zone arround the globe.

(d) Prophylactive management of retinal hole or hole-producing lesions discovered in the fellow eye.

(e) Grading of chorio-retinal adhesions produced by cryo is useful.

8.3.3. *Grading of chorio-retinal adhesions produced :*
Three possible grades are

(a) Weak adhesion with tissue reaction limited to pigment epithelium and outer layers of retina.

(b) Stronger Chorio-Retinal adhesion by causing localized destruction of Bruck's Membrane with participation of choroidal tissue in the scar.

(c) Strongest adhesion involves the participation of episcleral tissue through the perforation made on sclera (for which use of diathermy is more likely to be successful).

One distinct advantage of cryo over diathermy is that the former causes less damage to the over-lying the sclera and vitreous body lying inside the ocular coats.

8.3.4 *Guide to deliver the requisite dose :*

(a) Delivery of time-temperature regime is monitored by visual control (through direct or indirect ophthalmoscope aided by scleral depressor if necessary) though sensitivity and tissue response is still an unpredictable element.

(b) Experience, skill and knowledge of tissue-pathology however, guides the surgeon in this difficult decision.

(c) Aid in diagnoses, exploration and revealment of the holes or hole-producing lesions in the retina in the background of the eye type, gradually emerged.

(d) Importance of sealing and production of barrage of effective chorio-retinal adhesion around such lesion.

(e) The competition between diathermy, cryo application and photocoagulation in the production of effective sealing of retinal hole and formation of chorio-retinal adhesion are only the subsequent remifications of the central idea.

(f) The role of dubious effectiveness of the diathermy application (all based on lesions produced with antiquated model with past histological evidences) is still not settled.

(g) That each modality has its own advantages and disadvantages depending on the exact situation and clinical judgement of the surgeon is a current conscientious opinion. In this background the following points had to be judged. Regarding the relative merits of the contending modalities.

9. Relative merits and demerits of cryo-therapy diathermy (also photocoagulation)

9.1. Advantages of cryo-therapy :

(a) Less scleral damage and needs no scleral reactions ;

(b) Less incidence of endophthalmitis ;

(c) Reoperation easy and safer ;

(d) Safer for long ciliary artery or vortex vein ;

(e) Safer for staphylomatous sclera ;

(f) Cryo softens the globe facilitating a non-drainage scleral buckling ;

(g) Can be done on wet sclera even ;

(h) Possible to destroy small retinoblastoma even.

9.2. Advantage of diathermy over cryo :

(a) Diathermy lesions need not be continuous ;

(b) Diathermy does not disrupts the retinal pigment epithelium causing pigment fallout under retina with consiquent visual loss as is common with cryo-application.

(c) Chance of breakage of Bruch's membrane and sub-retinal haemorrhage is less common.

(d) Early sticky exudate formation occurs within three to four hours, unlike Cryo, which takes a few days generally.

(e) Detection of small holes in redeatched retina post-operatively when occurs is easier as no loss of colour contrast occurs.

10. Concluding remarks

(a) All the three forms of production of inflammatory chorio-retinal adhesion whether by application of heat (Diathermy or Photocoagulation) or its opposite like Cryo involves production of some positive damage to delicate ocular tissue (however controlled) so they call for critical judgement of the Surgeon employing them.

(b) Further refinement of equipments with advances of technology of temperature—Physics in the delivery of controlled and precise dose to the desired site of

application will make these applications more goal-oriented, resulting in better treatment of ailing patients and larger satisfaction to scientists, physicians and supporting personnel alike related directly and indirectly in the process.

References

Duane H D ed 1981 *Clinical Ophthalmology* Vol IV (Philadelphia : Herper and Row Publishers)

Rand R W, Rinfret A P and Leden H 1968 *Cryo Surgery* (Charles, C Thomas Springfield, Illinois, U.S.A)

Schepens C L 1983 *Retinal Detachment and allied diseases* Vol I (W B Saunders Company, Philadelphia, London, Toronto)

Spaeth C L ed 1982 *Ophthalmic Surgery, Principles and Practices* Chap 12 (W B Saunders Company)

Stallard's *Eye Surgery* 1989 7th ed M J Roper-Hall, Chap 10 p 358 (Butterworth International Edition)

References have been printed according to the author's style.